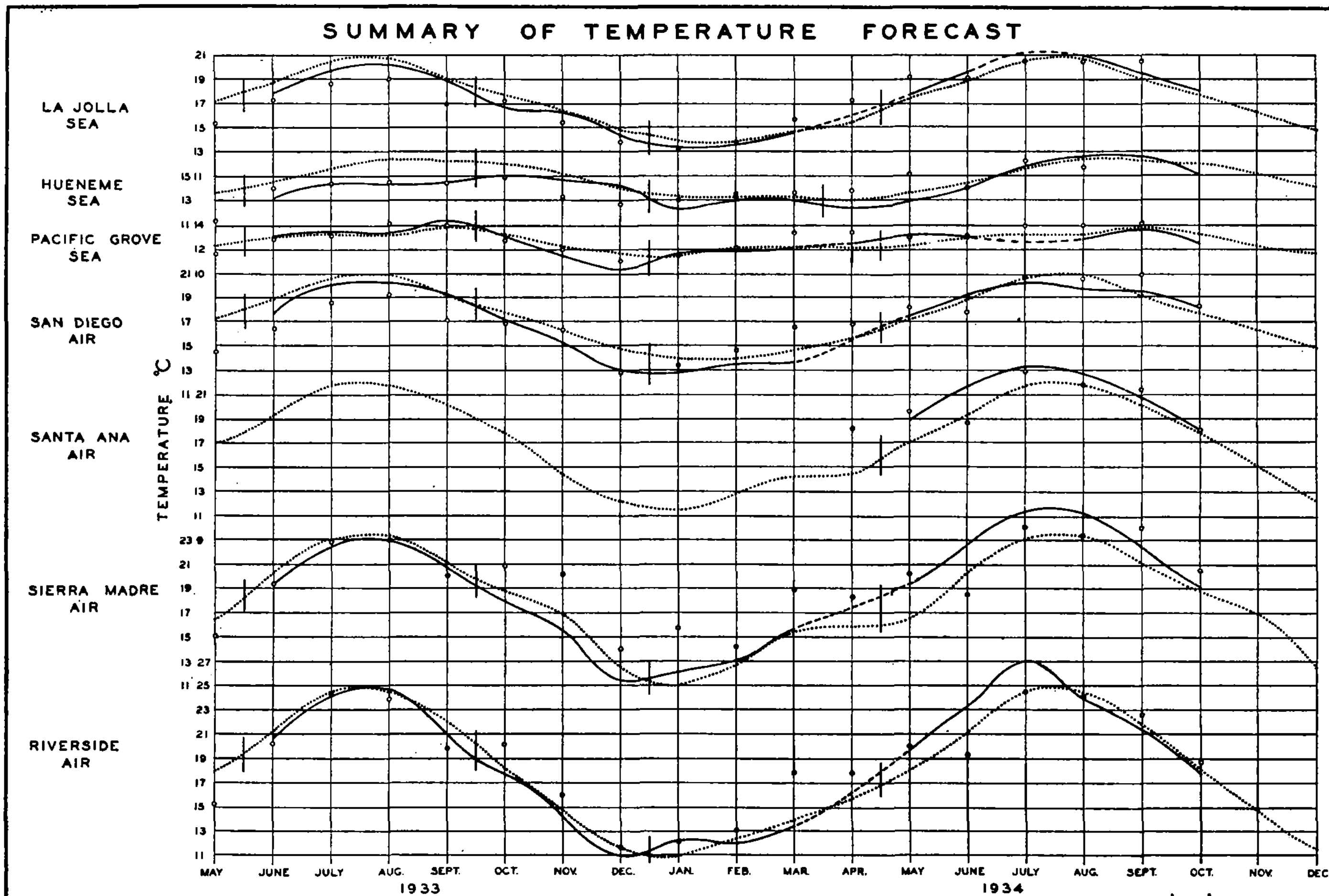

FORECAST ———, OBSERVED o, EIGHTEEN YEAR AVERAGE ...., FORECAST INTERVALS

FIG. 3.

AN INTERNATIONAL COMPARISON OF STANDARD BAROMETERS

By S. P. Fergusson

[Read before the American Meteorological Society, Atlantic City, Dec. 28, 1932; revised, September 1934]

For the measurement of short-period or day-to-day changes of atmospheric pressure and for almost all other purposes of meteorology and engineering, simple mercurial barometers of the "station" type having tubes about 6 mm in diameter are sufficiently accurate. But when pressures in different parts of the world are to be compared, and changes during long periods of time analyzed, instruments of greater precision become necessary; consideration must be given to the materials of which they are made and the slight variations of condition (chiefly of the vacuum) occurring in almost all barometers, even those of superior construction, through periods of many years. The only method of securing uniform, comparable records is that of comparing working standards, station or observatory barometers in current use, with "normal" or primary standards, the vacuum of which can be controlled and measured with high precision under "laboratory" conditions. Primary standards are costly and must be operated by trained physicists; but their importance is indicated by the design and use of several excellent examples in various countries of Europe.

In America, until recently, the sole dependence for international comparisons of pressures has been a few large-bore instruments of the Fortin type adjusted to agree with normals at the Kew Observatory, England, or similar instruments in France and Germany. One of the best examples is that of the importation, in 1878, by the United States Signal Service, under the most careful supervision, of 10 barometers by Adie of London, 4 of which are still used as standards by the United States Weather Bureau; another is the purchase by Professor Rotch of similar instruments by Hicks of London (no. 818 in 1885, no. 872 in 1887, and no. 1019 in 1892), for use at Blue Hill Observatory; and a third is that of an English barometer employed recently by the Canadian Meteorological Office in a comparision with the official standard of Canada; all of these instruments were certified at Kew. The Adie barometers and Hicks nos. 818 and 1019 have 12 mm tubes; that of no. 872 is 15 mm in diameter.

When Blue Hill Observatory was opened in 1885 the standard barometer was Green no. 2677, an instrument of the "station" type having a 6 mm tube, corrected to agree with the Signal Service standard, which, as stated, was that of Kew Observatory determined by means of the Adie barometers of 1878. Since January 1886 the standard of pressure has been that of Kew based upon the Hicks barometers of 1885, 1887, and 1892.

Differences developing among the barometers at Blue Hill, and between the standards of the Weather Bureau and Blue Hill during the period 1885 to 1892, led to the importation of the third standardized barometer in 1892, which, three times (1893, 1909, and 1932), has been taken to Washington for comparisons with the standards of the Weather Bureau, and once (1932) to Toronto for comparisons with the Canadian standard.

In March 1932 the Harvard Institute for Geographical Exploration imported an excellent instrument (Casella, no. 3289, having a 10 mm tube), of the type in use at Blue Hill, and in February 1933 another (Casella, no. 3306, having a 5 mm tube) of the pattern used on high mountains; the latter has a Kew certificate. These instruments have been used in a fourth comparison of American and English standards in which were included 4 instruments at Blue Hill, 3 at the Geographical Institute, 3 at the Weather Bureau, and 1 at Toronto. The Blue Hill standard of 1892 (Hicks, no. 1019) was first carefully compared with the other three instruments at Blue Hill; then, in succession, with the instruments at the Geographical Institute, the Weather Bureau and the Canadian Meteorological Office; after which it was recompared with the standards at the Geographical Institute and Blue Hill to ascertain whether changes had occurred during the journey to Washington and Toronto.

The usual precautions were observed during this series of comparisons: in every instance where Hicks no. 1019 was taken to another place it was exposed near the other barometers the day before actual observations were begun, the conditions of temperature, etc., kept as uniform as possible, and two or more series of about ten readings each were made on different days. Except at Toronto, the several groups of readings were made by different observers.

The following summary is offered: Hicks no. 1019 (1892), compared with Casella no. 3289 (1932), at the Institute for Geographical Exploration:

Before no. 1019 was taken to Toronto; means of 2 series of 10 readings of each instrument:

No. 3289	No. 1019	Difference	Corrected difference
Inches	*Inches*	*Inch*	*Inch*
29.8204	29.8222	−0.0018	+0.0012
29.2521	29.2524	+.0003	+.0027

After no. 1019 was brought back from Toronto and Washington; 1 series of 9 observations.

No. 3289	No. 1019	Difference	Corrected difference
Inches	*Inches*	*Inch*	*Inch*
30.3686	30.3673	+0.0013	+0.0043

Hicks no. 1019, compared with standard of United States Weather Bureau; 3 series of 10 readings each: Weather Bureau —no. 1019:

	Series 1	2	3	Mean
	Inch	*Inch*	*Inch*	*Inch*
Actual mean	−0.0095	−0.0055	−0.0081	−0.0077
Corrected mean	−.0065	−.0025	−.0051	−.0047

Hicks no. 1019, compared with Newman standard of the Canadian Meteorological Office, Toronto; 2 series of 10 readings each:

	Newman	No. 1019	Difference	Difference, after applying corrections
	Inches	*Inches*	*Inch*	*Inch*
1	29.778	29.786	−0.008	−0.002
2	29.5683	29.5713	−.003	+.003
Mean				+.0005

Comparison of Casella no. 3289 (1932) with Casella no. 3306 (1933) at the Geographical Institute: Mean difference of no. 3289 from no. 3306 (10 readings), +0.0063 inch; corrected difference, +0.0043 inch.

Differences of Blue Hill standard from Kew during the period 1885 to 1933: Blue Hill+Kew:

	1885	1887	1892	1893	1933
Barometer no.	2677; 818	818; 872	872; 1019	872; 1019	1019; 3306
Difference, inch	+0.004	−0.001	−0.005	−0.001	−0.0015

Differences of Blue Hill standards from those of Signal Service and Weather Bureau: Weather Bureau—Blue Hill:

1885	1887	1893	1909	1932
Inch	*Inch*	*Inch*	*Inch*	*Inch*
−0.000; −0.004	−0.005	−0.001	−0.003	−0.005

Differences between nos. 872 and 1019; 1019−872:

1893	1909	1932	
		Pressure 28 inches	Pressure 29.3 inches
Inch	*Inch*	*Inch*	*Inch*
−0.001	−0.003	−0.004	−0.006

The original corrections of the barometers under consideration are: No. 818, +0.009 inch; no. 872, −0.001 inch; no. 1019, −0.003 inch; no. 3306, +0.002 inch; the Newman standard, +0.003 inch.

The tube of no. 3306 is so much smaller than those of the other instruments that a longer series of comparisons of this instrument with others will be necessary to determine with satisfactory precision the present-day differences between the various barometers and the Kew normal or primary standard represented by no. 3306; however, the results so far indicate good agreement and the differences are not likely to exceed 0.004 or 0.005 inch (0.08 or 0.10 mm)—an amount ordinarily difficult to detect in current observations.

The comparisons at Blue Hill during the past 48 years indicate variable, slow changes in the largest instrument (Hicks, no. 872), but, since in some instances unusual variability of readings indicates unfavorable conditions for comparisons, it seems likely that the actual differences among these barometers are smaller than they appear to be. During these comparisons the four barometers referred to were cleaned and reconditioned for the first time since they were installed, although, due to the purity of the air at the observatory, the accumulation of oxide, etc., was too small to affect the accuracy of readings. No. 818 was found to contain air, but this, by fortunate chance, was removed by inverting the instrument, which, afterward, was found to have an excellent vacuum and to read apparently as at first; this method of removing air is rarely successful. No. 1019, the errors of which apparently have remained unchanged since it was purchased, appears to be the best of the four barometers and is considered the standard of the observatory.

Director Patterson states that the Newman standard, imported in 1839 and compared with the standard of the Royal Society at Somerset House, originally had a correction of −0.004 inch. Whether the British standard has been changed from that of the Royal Society is not known, but, in any case, the correction, now +0.003 inch, has not changed more than 0.007 inch in 93 years.

The author acknowledges indebtedness to Mr. Arthur Rotch, of Boston, who kindly contributed the expenses of travel incidental to this work, and to the Instrument Division of the Weather Bureau, and to Director Patterson of the Canadian Meteorological Office, for providing necessary facilities and assistance.

At the time the comparisons described herein were completed (early in 1933) no normal or absolute standard was in use in America. Since then two important advances in precision barometry have occurred, of which one is the new primary standard of the National Physical Laboratory, England, and the other the construction of an instrument at the United States Bureau of Standards. News of the latter will be welcomed by American meteorologists who have hoped for the maintenance of an absolute standard of pressure in this country. The new British standard is described in a paper, A New Primary Standard Barometer, by J. E. Sears and J. S. Clark, in the Proceedings of the Royal Society, A, vol. 139, 1933 of which the following summary is quoted:

> The paper contains an account of a new primary standard barometer recently installed at the National Physical Laboratory to serve as a basis of reference for all measurements relating to barometric pressures.
>
> The body of the instrument is constructed in stainless steel, with optically flat parallel glass windows through which the mercury surfaces are observed. These windows can be removed, if necessary, for cleaning, and the vacuum can be restored by means of suitable pumps whenever the instrument is required for use. The average temperature of the mercury column is ascertained by means of a mercurial thermometer with a bulb 30 inches long, immersed in a hole bored in the stainless-steel body parallel to the barometric column.
>
> Two micrometer microscopes are fixed, one above the other, to a massive vertical column which can be translated laterally so as to view either the mercury surfaces, or the divisions of a standard invar scale set up at the side of the barometer body. The height of each mercury surface is taken to be the mean of two microscope readings, one of the direct image of a horizontal cross wire projected into the space above the mercury, and one of the reflection of this image in the mercury.
>
> The design and general accuracy of workmanship are such that individual readings should be correct to the order of 0.001 mm. In practice it is found that the mean residual error of a single observation is of the order of 0.005 mm., this being probably attributable in the main to minute fluctuations of barometric pressure which are continually taking place, even when atmospheric conditions are reasonably steady.

The new instruments of the Bureau of Standards are described briefly in the following extract from a letter recently received from the Director of the Bureau:

> In testing mercurial barometers we are using a Fuess barometer as the standard which had been modified so as to have an all-glass cistern. Special methods of filling the tube have been developed in which the mercury is distilled into the tube while under a high vacuum. We have found that the vacuum above the mercury column when so filled holds for a number of years. This has been checked by intercomparison between 4 Fuess barometers, 3 of which are of the modified type. This intercomparison has usually taken place immediately after the refilling of one of the instruments.
>
> In order to eliminate possible errors due to the loss of vacuum above the mercury column we have recently constructed a mercurial barometer in which the vacuum space above the mercury column is connected to a mercury vapor pump and to a McLeod gage. It is thus possible to both control and measure the degree of vacuum. The scale and vernier from one of the Fuess barometers is used on this instrument which by comparison with the standard meter bar can be relied on to about 0.01 mm. We estimate the over-all accuracy which will be secured with this new arrangement to be ± 0.05 mm. of mercury. This accuracy is better than that of any portable barometer which is likely to be submitted for test.

METEOROLOGICAL CONDITIONS PRECEDING THUNDERSTORMS ON THE NATIONAL FORESTS

1. WESTERN AND CENTRAL OREGON

By W. R. STEVENS

[Weather Bureau, Washington, D. C., November 1934]

The great menace of thunderstorms to forested areas in all the western fire-weather districts of the Weather Bureau has been emphasized many times by all officials connected with the fire-weather work and by forest-protection agencies. In the region under consideration in this paper (western and central Oregon), lightning causes more than one-half of all the forest fires.

It is not apparent to the student of the daily weather map that lightning should be such a great fire-causing factor in this region, because few thunderstorms are observed at first-order Weather Bureau stations in this area. However, at higher elevations in the national forests of western and central Oregon, thunderstorms are frequent, and occasionally so widespread, with so many cloud to ground flashes, that forest-protection agencies are not able to cope with the situation unless they are warned at least a few hours in advance.

It is the purpose of this paper to discuss thunderstorms, particularly in relation to the national forests of western and central Oregon, and to present an analysis of the meteorological conditions that ordinarily precede their occurrence in that region.

CAUSES OF THUNDERSTORMS

The thunderstorm is the result of vigorous vertical convection of humid air. The thunder and lightning which attend the storm play no part in its mechanism.

When vertical convection of air occurs, the air is said to be unstable. Instability may be brought about by strong surface heating; by overrunning of one layer of air by another at a considerably lower temperature; by underrunning and uplift of a saturated layer of air by a denser layer; and by forced ascent of humid air masses up mountain slopes.

There are two classes of thunderstorms, (1) the heat thunderstorm, and (2) the cyclonic thunderstorm. This classification is based upon the cause of the instability which produces the storms. There are other classifications of thunderstorms, but this one suits best for the present discussion.

Conditions are favorable for the genesis of heat thunderstorms when the pressure is nearly uniform and slightly below normal over a wide area. When this situation prevails, the winds are light and the surface air becomes